7 PINES 2009

Note Title 25/09/2008

(A) The basic idea, as I understood it, was to have a meeting devoted to the theme of "effective field theories in condensed matter physics".

From a historical perspective, one can discern the following important developments:

1) QUASIPARTICLES, ORDER PARAMETER, BOSE & FERMI LIQUIDS

This development took place from c. 1932–1957. It is almost entirely due to the Landau school. The idea of an interacting quasiparticle gas to describe the low energy states of a quantum solid, liquid, or gas; the order parameter for magnets, superfluids, & other systems undergoing a phase transition, and the Landau theory of such phase transitions, Ginzburg-Landau theory of superconductors, theory of superfluid ^4He, theory of Fermi liquids; and ODLRO (cf also F. London, L. Onsager).

All of this laid the foundation of modern condensed matter physics. It was later used in nuclear physics and in elementary particle physics.

2) BCS THEORY

Bogoliubov (1947) develop first weak-coupling field theory of Bose superfluid. Extended by BCS (1957) to superconductors; field theory by Abrikosov, Gorkov (connect to Ginzburg-Landau), and Nambu.

3) QFT IN CONDENSED MATTER

The development by Feynman, Schwinger, Tomonaga, etc., of relativistic QFT had a rapid effect in condensed matter. QFT formulation of electronic, superfluid, magnetic, etc systems; & non-perturbative problems like polaron (Landau-Pekar, Feynman).

4) IMPURITIES & KONDO PROBLEM

Effective Lattice field theory for magnetic impurities (Friedel 1960, Anderson, 1961), discovery of Localisation (Anderson 1958), discovery of infra-red divergences (Kondo, 1964), and realisation that this was a fundamental new kind of QFT, with "asymptotic freedom" at low energy; solution of problem using instanton methods (Anderson, Nozières, late 60's) and finally RG (KG Wilson, 1971) Formulation as a new kind of Fermi liquid theory (Nozières, 1974).

5) RENORMALISATION GROUP (RG)

Early formulations (Bogoliubov, Gell-Mann/Low, Landau school, etc), lead to new way of formulating effective field theories in condensed matter (Kadanoff, Wilson, Fisher, 1966-74) and particle physics. Solution of 2nd-order phase transitions, beyond Landau theory, & Kondo problem. Later elaboration to many other problems

6) QUANTUM SOLITONS → FRACTIONAL CHARGE

Discovery of vortices (Onsager 1950, Feynman 1954, Abrikosov 1957) in superfluids & superconductors leads to gradual realisation that almost any non-trivial QFT will have a quantum soliton sector → formulation of interacting quasiparticle/soliton effective theories. Then, in 1976, simultaneous discovery of fractional charge in such theories, in condensed matter (Schrieffer et al., for polyacetylene) and in relativistic field theory (Jackiw & Rebbi).

7) FQHE + TOPOLOGICAL FIELD THEORY + FRACTIONAL STATISTICS

Discovery of fractional statistics (Leinaas & Myrheim, 1977). Realisation by Halperin in 1984 that Laughlin's theory of the Fractional Q. Hall effect (1983) had quasiparticles with fractional statistics. Hierarchy theories for these quasiparticles (Halperin, Haldane, 1984) and composite fermion theory (Jain, 1987-90). Repeated attempts to formulate an effective field theory for this, which has to be a topological field theory (Zhang et al (1987), Halperin et al (1993) Wilczek, Witten (1994)). None of these yet completely successful.

8) EFFECTIVE FIELD THEORIES of DISORDERED SYSTEMS

Formulation of localisation problem as a field theory, using replica trick (Edwards & Anderson, 1975), and application of RG (the "Gang of 4", Anderson, Thouless, .., 1979).

Formulation of "spin glass" problem as an effective field theory (Edwards, Anderson, 1975), and repeated attempts to solve this field theory since then (Parisi, 1983, et seq.), including the "frustration" phenomenon (Anderson, Toulouse, 1976).

9) TUNNELING & EFFECTIVE FIELD THEORIES

Discovery of instanton (Langer, 1967). Use of instantons to solve key problems, in condensed matter physics (Anderson et al., 1969) and particle physics ('t Hooft, Polyakov, 1974), and realisation that effective field theories are radically altered by these. Formulation of such theories for tunneling problems, using a quasiparticle approach (oscillator bath) approach (Caldeira-Leggett, 1983)

10) LATTICE FIELD THEORIES.

Formulation of Hubbard model (Peierls 1937, Mott 1949, Anderson 1950-52, Hubbard 1963-65), and idea of "Mott-Hubbard transition"). Realisation of deep nature of this problem (1960-1987) Formulation of lattice gauge theory (KG Wilson, 1973). Formulation of Hubbard model as a lattice gauge theory (Anderson et al, 1987). This theory is still unsolved. Possibly has some features in common with string theory.

11) LOW-DIMENSIONAL EFFECTIVE FIELD THEORIES.

First such theory (for interacting electrons in 1-d) by Tomonaga (1950). Extension of these ideas by Luttinger (1964) Haldane (1979) & others. Discovery of "Haldane gap" by Haldane (1983), showing that many of these theories had a topological component. Solution of Kondo problem by mapping to 1-d effective field theory (Tsvelick, Wiegmann, Andrei, Lowenstein, 1979), & use of Bethe ansatz.

Note that items 7, 8, and 10 are still wide open, ie., the effective field theories have been formulated but their main features are still not understood - these are central problems in physics.

The itemised history above shows how things have unfolded. We need to pick & choose from all of this, since there is a lot there.

The plan given below takes into account:

a) Interests of other people on the board, which lean quite strongly to particle physics & gravity.

b) A desire to set a proper historical perspective on at least some of these developments.

c) A desire to have some discussion of important philosophical questions associated with effective field theories. (particularly those in condensed matter physics).

d) interest of the potential speakers in giving an accessible and stimulating talk, & in being involved in discussion.

(B) The following is a list of potential speakers or at least attendees for this proposed meeting; along with comments and a "star rating" (the number of stars on the LHS indicates my estimate of their importance to the meeting).

(1) The SCIENTISTS.

* E. Brézin (ENS, Paris) : RG and critical phenomena. Would give a v. good picture of the historical development of this whole field. He is by training a particle theorist, with extensive stat mech.

*** Michael Fisher (Maryland) : RG & critical phenomena. Good picture of historical development & present state of the field. He has a more stat mech / cond mat perspective.

*** LP Kadanoff (Chicago) : RG & critical phenomena, & non-equilibrium phenomena. Good picture of historical development & present state of the field, from cond mat / stat mech perspective.

* JS Langer (UCSB) : Phase transitions, non-equilibrium, & non-perturbative phenomena in field theory. Historical perspective & present state.

* B.I. Halperin (Harvard) : Classical & Q. Critical phenomena; FQHE, anyons, topological Q. Fluids. Has complete overview of all these developments.

** R. Jackiw (MIT) : Particle theorist who also played key role in development of ideas of fractional charge, topological Q. fluids, and has worked on the condensed matter applications as well.

* M. Stone (Urbana) : Mathematical physicist who has given excellent surveys of developments of FQHE, of low-dimensional systems, and of topology in condensed matter systems.

* R. Shankar (Yale) : Has worked in particle physics & CM physics. Exceptionally clear & entertaining speaker who has written masterful review of RG applied to CM systems.

*** D. Khmelnitskii (Cambridge) : Very unusual CM theorist who knows more than anyone else in the world about the history of the Soviet school of physics (and a great deal about the development of Western thinking).

* I. Khalatnikov (Israel) : Former director of Landau institute, now retired, author with Landau of theory of superfluid ^4He (also contributed to General Relativity). Very good historical source on development of Soviet school and of CM physics in general.

* N. Nagaosa (Tokyo) : Best known Japanese CM theorist, expert on topological Q. fluids and on Hubbard model. V good source on development of Japanese ideas (Tomonaga, Kubo, Kondo, etc).

**** P.W. Anderson (Princeton) : The authoritative source on many of the developments to have occurred in CM physics in the last 50 yrs in the West, both from physics point of view and the historical development. Good on philosophical issues.

* P. Nozières (Grenoble) : One of the major thinkers on development of Fermi liquid theory,

superfluidity, the Kondo problem, and RG; played a major role in development of the "effective Hamiltonian" idea. Good source on historical development.

** J. R. Schrieffer (Florida): Played key role in development of superconductivity, and of fractional charge. Good source on development of CM ideas in the last 50 yrs.

* G. Baym (Urbana): Has contributed to theory of Fermi liqs, superfluids & superconductors, as well as nuclear & particle physics. Good historical source on the development of CM physics.

**** A. J. Leggett (Urbana): Major contributor to development of ideas on Fermi liquids, superfluids, and on non-perturbative aspects like tunneling. Good source on historical developments, and on the entire philosophical background.

(2) THE PHILOSOPHERS & HISTORIANS

*** J. Butterfield (Cambridge): Has written extensively on effective field theories; in last few years has worked on these in context of RG and condensed matter with several students.

* P. Mainwood (Oxford?): Wrote PhD thesis (2006) on emergence & RG, in context of CM physics. Part of this thesis involves debate with R. Batterman.

** R. Batterman (Ontario): Has written quite extensively on emergence, & related topics, in CM physics, & on RG, and on effective theories.

** S. Hartmann (Munich / Tilburg): Has written on effective field theories in CM physics and in particle physics, & also discussed the reductionism vs emergence in this context.

T Y Cao (Boston): Has written extensively on relativistic Quantum Field theory (including with Schweber). No obvious interest in condensed matter.

*** K. Gavroglu (Athens): Wrote a well-known biography of F. London; familiar with many aspects of history of superfluidity & of low-temperature physics.

*** L. Hoddeson (Urbana): Wrote a well-known biography of J. Bardeen, as well as several articles on development of condensed matter theory in the West.

* N. Cartwright (LSE): Has written over the years on different aspects of effective theories, as well as on many other topics in HPS.

* Sang Wook Yi (Seoul): Wrote an interesting PhD thesis on effective theories in condensed matter physics (w/ Cartwright), including extensive discussion of RG.

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OTHER NAMES I have looked at a few other people, in some cases following suggestions made by various people. These include:

L.M. Brown (Historian of physics). Not sure how much he knows about condensed matter.

D.J. Thouless (U of W): V. important contributor to our understanding of superfluids, vortices, FQHE, glasses, and many other things. Not sure how interested he would be in philosophical aspects.

J. Cardy (Oxford) : Expert in RG, written nice texts. He is a mathematical physicist, might not be very interactive.

S. Schweber (Brandeis) : Well known historian of physics, specialising in particle physics. Seems to have a little bit of tunnel vision towards condensed matter.

C. Domb (Kings, London) : Statistical mechanics theorist who has written several historical books on development of condensed matter physics Probably quite old now?

P. Teller (UC Davis) : Historian & philosopher of physics, has written extensively on effective field theories, mainly in particle physics. Not sure how interested he is in condensed matter. He is now retired.

M. H Krieger (USC) : Rather unusual person, PhD in physics, Prof of urban planning, but has written v. extensively on physics & mathematics (he is a Fellow of the APS) including topics overlapping with this meeting. Need to know more about him - comments?

D. Wallace (Oxford) : Has written on effective field theories in particle physics. Not clear to me how much he knows or cares about condensed matter physics.

E. Castellani (Florence) : Has written on effective field theories. Her work seem rather detached from the main issues (at least to me).

A. Grünbaum (Paris) : Suggested to me by Don Howard, but I don't see why (except that Don tells me he is a bright fellow).

R.I.G. Hughes (Caroline): Written extensively about QM. Not clear he has much knowledge of (or interest in) the issues relevant to this meeting

C. Joas (Berlin): Has written a few not terribly interesting papers on technical aspects of FQHE physics. Now in Berlin centre for HPS — not clear he has produced anything.

A number of other suggestions were made for reasons that are quite obscure to me:

Spencer Weart
Gary Weisel
Daniela Monaldi
} I can't see that the interests or writings of these people have anything to do with the proposed meeting.

I am hesitant to propose a final plan for the meeting until the foregoing has been discussed. However, to focus things a little, here is one possibility:

- Development of Effective theory in CMT (I)

  PW Anderson (Western development)
  D Khmelnitskii (Soviet development

- Development of effective theory in CMT (II)

  L. Hoddeson (American CMT)

K Gevragh (Superfluidity).

- Effective Field Theories in CMT

J Butterfield
S Hartmann
(or Batterman, Cartwright)

- Fermi Liquids & superfluids

AJ Leggett (Fermi liquids & superfluids)
JR Schrieffer (superconductivity).

- RG and Effective Field Theories in CMT

M. Fisher RG and classical physics
R. Shankar RG and Quantum CMT.

- Fractional Charge & Topological Field theory.

- R. Jackiw (Fractional charge)
- M. Stone (FQHE and fractional statistics).